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**Task 4
Analysis of Potential Alternative Uses for CRT Glass
*Draft***

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Prepared For:

**U.S. Environmental Protection Agency
Office of Solid Waste
Ariel Rios Building
1200 Pennsylvania Avenue, NW
Washington, DC 20460**

Prepared by:

**Dynamac Corporation
20440 Century Boulevard
Suite 100
Germantown, MD 20874**

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Analysis of Alternative Uses for CRT Glass

1. Introduction

This report identifies and examines potential alternative uses for used cathode ray tube (CRT) glass. In December 1999, Dynamac prepared a paper that provided an overview of potential uses and applications for the recycling of CRTs. The current report updates and expands upon the potential uses for CRT glass. The focus of this report is on new CRT glass recycling technologies. Established technologies, including recycling into new CRT glass and recycling at a lead smelter, are only briefly mentioned for report completeness.

It should be noted that CRT glass recycling is still an emerging industry; therefore, limited information is available on new recycling technologies. Several of these technologies continue to be studied, and additional information may be available by contacting universities and other research institutions.

Markets for computer-derived components and scrap vary tremendously. Therefore, to facilitate recycling, it is necessary to grade the different components using a uniform system. According to Mid-Atlantic Consortium of Recycling and Economic Development Officials (MACREDO), the following grades are included in the CRT recycling category:

Whole VDT/TV Scrap	Whole video display terminal/television (VDT/TV) Scrap consists of whole-assembled computer monitors, VDTs and television sets suitable for dismantling (uncrushed/unbroken).
CRT Scrap	CRT Scrap consists of scrap whole or broken CRTs, may contain cores and windings, but must be free of metal and plastic frames. This is a benchmark grade on the Computer & Electronics Recycling Index and the Andela Scrap Glass Composite Index.
1/8" Recovered CRT Glass (Andela #16)	1/8" Recovered CRT Glass consists of CRT glass processed and sized to -1/8"(inch) ¹ . Must be free of cores, metal windings and other foreign materials.
3/8" Recovered CRT Glass (Andela #17)	3/8" Recovered CRT Glass consists of CRT glass processed and sized to -3/8"(inch). Must be free of cores, metal windings and other foreign materials.
CRT Tailings	CRT Tailings consist of CRT processing rejects and

may include screens, cores, coils, windings and residual metal from gun remnants.

Other CRT Scrap

Other CRT scrap consists of other CRT scrap not included in the listed grades.

According to the Recyclers World web site, the Computer & Electronics Recycling Index and the Andela Scrap Glass Composite Index are yardsticks to measure changes in the recyclable commodities market. These changes are reported in "points," not in dollar amounts.

2. Established Recycling Alternatives for CRT Glass

In the past few years, many States have passed legislation regulating the disposal of CRTs and CRT glass in municipal landfills. The States either prohibit their disposal, designate them as hazardous waste, or designate them as universal waste. Under these different regulations, many of the States recognize glass-to-glass recycling and secondary lead smelting operations as acceptable recycling alternatives. Since these recycling methods have been investigated and are widely accepted, this report will only briefly discuss these alternatives, and instead, focus on areas of emerging technology.

In a three-month study (July 31 to October 31, 1999) by Minnesota's Office of Environmental Assistance, the State identified that 575 tons of used electronic products were collected at drop-off sites. From those 575 tons, the State recorded that 22.5 tons were sent to a glass recycler for use by a glass manufacturer, and 113 tons were sent to a lead smelter. The Minnesota report noted that CRT glass recovered in the State has traditionally been managed in a glass-to-lead loop through various smelting operations. They also noted that CRT glass recycling markets that return CRT cullet to the CRT manufacturing process are located on the east coast of North America and are costly to ship product to. However, during the study, they found that it cost \$90 per ton to manage CRT glass in a glass-to-lead loop, whereas CRT glass managed in a glass-to-glass loop cost \$50 per ton.

2.1 Glass-to-Glass Recycling

The most established use for CRT glass is closed-loop glass-to-glass recycling. Following CRT disassembly, the low lead panels are separated from the high lead frit and funnel. Once the glass is separated, the steel shadow mask is removed, and the panel glass is cleaned to remove the phosphorus coating. The glass may be broken for shipment to CRT manufacturers.

At the March 22, 2001 Electronics Recycling Infrastructure Workgroup Meeting, it was noted that glass-to-glass recycling is not available on the west coast. It is also important to note that most references defined glass-to-glass recycling as recycling back into new CRT glass. However, the Minnesota Office of Environmental Assistance definition of glass-to-glass recycling included the manufacturing of CRT glass into new lead glass items, *e.g.*, lead glass bricks.

2.2 Lead Smelting

The process of lead smelting reclaims lead and possibly other metals from CRTs for general use and uses the glass as a fluxing agent in the smelting process itself. CRT glass is a direct replacement for silica or sand. Since smelters purchase sand, the use of CRT glass as an alternative fluxing agent lowers operating expenditures due to lower costs associated with CRT glass substitution. Secondary lead smelters have been used for many years to recover lead from automotive batteries. According to a Cascade Asset Management survey, there are approximately 11 secondary lead smelters in North America.

The smelting process removes any lead or other heavy metals from produced glass, and, in effect, "cleans" the glass. A drawback is that smelting must be followed by other processes before the materials are manufactured into glass, and the total processing cost may be higher than direct recycling. In fact, the Minnesota report noted that the transportation and material preparation at the smelters exceeds the monetary value of the lead and silica. In any event, broken, mixed and contaminated glass can be smelted rather than using it for glass production and risking contamination of the glass making process.

3. Emerging Recycling Alternatives for CRT Glass

Because of the heavy metals in CRT glass, many recycled glass markets are unavailable. However, certain companies are currently developing technologies that immobilize the heavy metals. Recycling markets may also expand as other companies and research facilities examine the risk of using recycled materials such as CRT glass. Therefore, some of the markets discussed below are limited, but may expand pending further study of the new technologies.

3.1 Highway Products

Recycled glass materials are currently being used in road construction in several States. However, this market is often limited to glass that is free of heavy metals. To help determine if CRT glass can be used as an aggregate substitution in highway construction, the Recycled Material Resource Center in Durham, North Carolina, in partnership with the Federal Highway Administration is currently developing a risk analysis framework for the beneficial use of secondary materials. The study is scheduled to be complete in March 2003 with the goal of providing a simplified risk assessment approach for State environmental agencies to support beneficial use determinations. This project involves understanding water movement in the roadway environment for the development of a risk model to realistically estimate leachate concentrations.

In addition to research of heavy metal mobility from CRT glass, the company Proactive Environmental Research and Development, Inc. (PERDI) has developed a technology that immobilizes lead from CRT glass. PERDI grinds the CRT glass into sand-like granules and mixes the glass with an additive to immobilize the lead. Reportedly, the glass product may be used as road base or as a drainage grade aggregate.

Researchers at Texas Tech University found that glass cullet was suitable for a wide variety of uses in highway construction and an excellent supplement or replacement for gravel in many construction applications. Texas allows up to 20 percent glass cullet for embankments, backfill that supports roadbed, and flexible base; up to 5 percent for asphalt stabilized base and open-graded bases; and up to 100 percent for backfill that does not support any portion of the road bed. In Minnesota, studies have been conducted using 5 percent glass cullet mixed with traditional recycled concrete and salvaged bituminous. Also, Minnesota is testing class 6 aggregate consisting of 10 percent recycled glass in the road base and 100 percent recycled glass in the first 75-millimeter (mm) layer of the 600 mm subgrade. Most States are also mixing cullet with asphalt and using this "glassphalt" as road and sidewalk paving material.

3.2 Copper Smelting

The process of copper smelting reclaims copper and possibly lead. Several reports stated that copper smelters do not recover the lead, but instead, "fix" the lead in slag. The Chelsea Center for Recycling and Economic Development report noted that Noranda's Horne copper smelter in Toronto, Canada accepted CRTs and was adding a new lead recovery technology in 2000. In copper smelters, concentrate, other metal-bearing feeds, and flux are introduced into the reactor. CRT glass has been found to be a suitable substitute for sand or silica as a fluxing agent.

Most of the information on CRT recycling referenced using lead smelters, but a few references to copper smelters were found in the literature. In Illinois, United Recycling Industries one of three integrated recycling operations, works in partnership with COMPAQ's computer take back program. United Refining & Smelting Co. is a major refiner of precious metals, primarily gold, silver, platinum, palladium and copper. Asset Recovery in Saint Paul Minnesota accepts CRTs for repair and recycling and identifies using a copper smelter for metals recovery (no further information was provided). The Minnesota report identified that North American copper smelters are large consumers of CRT glass which utilize the glass as a fluxing agent. The report also noted that transportation and material preparation at the smelters often exceeds the monetary value of the silica.

3.3 Industrial Panels

CRT glass may also be recycled into glass panels for industrial applications such as skyscrapers, hospitals, and office buildings. Many applications of this market use leaded glass for radiation protection. As a result, CRT glass is an attractive alternative because of its high lead content. Co-mingled CRT glass of all types can be utilized in this application. According to the Chelsea report, one company collects and sells CRT glass to a Japanese glass manufacturer to produce the panels.

3.4 Radiation and Acoustic Barriers

BusinessWeek Online reported that the New Jersey Institute of Technology (NJIT) Multi-Lifecycle Engineering group has produced leaded glass blocks utilizing recycled CRT glass. These blocks can be used as radiation barriers or as architectural construction materials. NJIT

research has also produced a ceramic tile from ground CRT glass which, like the glass block, can be used as radiation shielding. NJIT is also producing flexible acoustic and radiation barriers using powdered CRT glass mixed with polymer materials such as rubber. The CRT glass replaces powdered metal or oxide. The use of CRT glass is advantageous because it requires minimal processing for the applications, and no sorting or separation of glass chemistries is required. The CRT glass processing is limited to crushing and cleaning to remove the phosphorous coatings.

As noted earlier, the Minnesota study shipped 22.5 tons of CRT glass to a glass recycler (Dlubak Glass) in Ohio for use by a glass manufacturer. In the report, they identified that this included manufacturing into new CRTs and a few other acceptable commodities, including glass radiation shielding and filaments in incandescent lights.

3.5 Fiberglass

According to the Glass Packaging Institute, recycled glass used in the manufacture of fiberglass now constitutes the second highest volume of post-consumer glass. Industry standards for product quality and consistency are very high. Universal Cullet reported that use rates of up to 60 percent cullet were possible without impacting quality. The use of cullet reduces costs through energy savings.

3.6 Decorative Tile and Paving Products

Futuristic Tile LLC has developed a patented technology for the production of masonry-like building products using recycled glass. The tiles can be produced in a range of colors and textures. The process utilizes 100 percent recycled glass cullet, including approximately 85 percent three-color mix or other silica-based waste in the bottom layer and 15 percent clear glass cullet in the top layer. Companies such as Terra Green Ceramics, Inc. are manufacturing tile using over 55 percent recycled glass. Experimental research shows that CRT glass is acceptable as a raw material in the bottom layer, while the feasibility of utilizing CRT glass in the top layer requires further testing.

Studies conducted by the Clean Washington Center (CWC) have shown that the strength and absorption properties of well made recycled glass tile (US sieve #6-#16 glass particles), are as good as, and often much better than, American Society for Testing and Materials (ASTM) requirements for similar types of material. Because the modulus of rupture of a material is related to the thickness of the tile squared, the required thickness of glass tiles is 0.71 times that of concrete tiles, in order for them to carry the same load. For example, if it were desired to produce a glass tile with a bending resistance equivalent to that of a one inch (25.4 mm) thick concrete tile, then a 0.71 inch (18 mm) thick glass paving tile would be required. Also, a concrete tile having the same bending resistance as a one inch (25.4 mm) thick glass tile would have to be 1.41 inches (35.9 mm) thick.

Tom Drake of 5R Processors in Wisconsin is producing landscape bricks made from recycled CRT face plate glass and concrete. The Oak Ridge National Recycle Center plans on beginning

production of the same bricks in 2001. Syndesis, Inc. is producing a pre-cast lightweight concrete material utilizing recycled glass chips, plastic, coal fly ash, and metal shavings. It is being used in a variety of architectural applications, including outdoor furniture and pavers.

3.7 Industrial Abrasives

Finely ground glass can be used in place of sand or slag-based abrasives. According to a study conducted by the CWC, ground glass abrasives are angular and have the ability to cut many coatings. Recycled glass may be superior to other abrasives because it produces a "white metal" finish, it does not contain chlorides or other salts that can accelerate corrosion, it generates less dust which could reduce post-blast cleanup costs, can be reused more than lower cost abrasives, and it is less dense and may produce lower surface embedment. The study found that recycled glass competes on a cost basis with copper and nickel slag-based abrasives. A number of companies across the country indicated they provide recycled glass for abrasive cleaning, *e.g.*, Universal Ground Cullet, TriVetro Corporation, Vitreous Environmental Group, Glass Recycling, Inc., and Strategic Materials, Inc.

The CWC study compared recycled glass abrasives to copper and nickel slag abrasives. The glass tested was VitroGrit #16, VitroGrit #30, and VitroGrit #40. There are a large number of independent variables to contend with for a given blasting job, but dust generation can be somewhat controlled by the blast technician by varying the blast pressures, abrasive feed rate, nozzle placement, among other factors. The recycled glass and copper slag produced similar amounts of dust; however, the nickel slag abrasive generated far more dust.

3.8 Coating Products

Another CWC study used ground glass (100-325 mesh) to replace crystalline silica products found in elastomeric roof coating products. The study found that the roofing material with 1.25 pounds of glass per gallon of coating product compared favorably to products without recycled glass. The glass can be substituted directly on a volume or weight basis for the current crushed crystalline silica products. The roof coating with the recycled glass performed similarly to the current commercial coatings with similar flexibility and water resistance. It was determined that the glass with a size of 100-200 mesh is best suited for high-thickness coatings (12-30 mils dry film thickness), like the roof coating. Glass that is approximately 325 mesh could be used for interior flat latex paint. Based on this study, Eco Chemical, Inc. is planning to pursue product development of this and other coatings containing recycled ground glass.

3.8 Clay Fluxing Agent

Vitreous silicates are generated during the maturation of clay bodies which act as fluxes, reducing clay body maturation temperatures. Glass is already a vitreous silicate, and studies by the CWC and U.S. Bureau of Mines found that the addition of recycled glass to clay body raw materials could increase the efficiency of clay body firing and therefore be a value-added application for recycled glass fines. The Bureau of Mines found that by substituting glass for one-half of the clay reduced the firing temperature by 500°F.

The CWC study used two grades of glass fines for this project, grades 140F and 325F; however, the best batches in the project were made using the 325F grade. The primary problem was encountered with clays containing greater than 20 percent glass. These clays would quickly stiffen after mixing, therefore rendering them unusable. The study found that the best application was press molding, which does not require a highly plastic clay body.

Universal Ground Cullet promotes using recycled glass as a clay additive to promote brick formation. The company has found that bricks made with recycled glass meet ASTM specifications. Using recycled glass as a fluxing agent reduces firing time and temperature, thereby reducing fuel consumption.

4. Export

Several companies have identified exporting CRTs. According to the Chelsea Report, Fortune Plastics and Metals exports CRTs to China for processing at a company-owned subsidiary. The CRT glass is granulated and sent to pesticide bottle manufacturer for manufacture into glass bottles. The Chelsea Report estimates the current export capacity at 100 tons/month.

5. Current Initiatives

The Electronic Industries Alliance (EIA), in cooperation with contributing manufacturers Canon, Hewlett Packard, JVC, Kodak, Nokia, Panasonic, Philips Electronics, Sharp, Sony, and Thomson, announced in June 2001 the development of an innovative electronics collection and recycling pilot project. Scheduled to launch in October 2001, the pilot will test several different models of electronics collection and recycling. From the pilot, participants hope to generate data that will help guide the development of a cost effective and efficient long-term electronics recycling program. The EIA believes that the Electronics Recycling Pilot Project will help provide a solid base of knowledge that can be used to determine the best long-term approach for any electronics recycling program. The pilot will take place in selected states, and several different models of collection, recycling, and financing will be tested for a one-year period.

In May 2001, the International Symposium on Electronics and the Environment was held in Denver, Colorado highlighting current initiatives. From the available agenda, possible papers or contacts that may provide useful information are:

Edward Grenchus, Robert Keene, and Charles Nobs (IBM) - "The Quest for Environmental Productivity and Improvements at IBM's Demanufacturing Operation and Asset Recovery Center"

Douglas Smith and Mark Small (Sony Electronics) - "End of Life Recycling through Free Enterprise"

Maria Leet Socolof and Jonathan Overly (University of Tennessee) - "Life-Cycle Environmental Impacts of CRT and LCD Monitors"

Rolf Steinhilper (Fraunhofer Institute for Manufacturing Eng and Automation) - "Remanufacturing - the Key Solution for Transforming Downcycling into Upcycling of Electronics"

K.H.P. Janssen and T.J.J. van der Horst (TNO Institute of Industrial Technology) - "Method to Assess the Recyclability of Televisions from the Perspective of Consumer Organizations"

Joy Williams and Li Shu (University of Toronto) - "Comparison of Remanufacture Waste Streams for Electronic Products"

The National Electronics Product Stewardship Initiative (NEPSI), met for the first time this year in San Francisco, California. The group was organized in April 2001 and consists of 45 participants, split evenly among industry, government, recyclers, and environmental groups. Their most recent meeting focused on developing models for financing and operating used electronics collection programs. The group has agreed to meet six times through 2002.

The US EPA Region III has launched a pilot Electronics Recycling Project to establish electronics collection programs by October. Participants in the project include government, industry and not-for-profit organizations that are working together on issues such as regulatory relief, financing and publicity.

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¹A "-" before the sieve size indicates the particles pass through the sieve.